Acknowledgments

Research supported in part by grants from the North Carolina Small Grain Growers Association. We wish to recognize the Wheat Genetics Resource Center at Kansas State University for their assistance in the development of these germplasms.

References

Jarve, K., H.O. Peusha, J. Tsymbalova, S. Tamm, K.M. Devos, and T.M. Enno. 2000. Chromosomal location of a *Triticum timopheevii*-derived powdery mildew resistance gene transferred to common wheat. Genome 43:377–381.

Leath, S., and M. Heun. 1990. Identification of powdery mildew resistance genes in cultivars of soft red winter wheat. Plant Dis. 74:747–752.

Long, D.L., and J.A. Kolmer. 1989. A North American system of nomenclature for *Puccinia recondita* f. sp. *tritici*. Phytopathology 79:525–529.

Murphy, J.P., R.A. Navarro, and S. Leath. 2002. Registration of NC99BGTAG11 wheat germplasm resistant to powdery mildew. Crop Sci. 42:1382.

Starling, T.M., C.W. Roane, and H.M. Camper, Jr. 1986. Registration of 'Saluda' wheat. Crop Sci. 26:200.

Registration of Six Great Northern Bean Germplasm Lines with Enhanced Resistance to Rust and Bean Common Mosaic and Necrosis Potyviruses

M.A. Pastor-Corrales,* James D. Kelly, James R. Steadman, Dale T. Lindgren, J.R. Stavely, and Dermot P. Coyne

Great northern bean (*Phaseolus vulgaris* L.) germplasm lines BelMiNeb–Rust and Mosaic Resistant (BMN-RMR)-8 (Reg. No. GP-247, PI 642014), BMN-RMR-9 (Reg. No. GP-248, PI 642015), BMN-RMR-10 (Reg. No. GP-249, PI 642016), BMN-RMR-11 (Reg. No. GP-250, PI 642017), BMN-RMR-12 (Reg. No. GP-251, PI 642018), and BMN-RMR-13 (Reg. No. GP-252, PI 642019) were developed by the USDA-ARS Beltsville Agricultural Research Center, Beltsville, MD, in cooperation with the Michigan and Nebraska Agricultural Experiment Stations. To our knowledge, these are the only great northern bean lines in the world to combine four genes for resistance to all known races of the hypervariable bean rust pathogen, *Uromyces appendiculatus* (Pers.:Pers.) Unger, with two genes for resistance to all known strains of the seed-borne bean common mosaic (BCMV) and bean common mosaic necrosis (BCMNV) potyviruses. These white-seeded great northern dry bean germplasm lines are high yielding and upright, short vine type II growth habit plants.

Rust is a disease of dry and snap beans that occurs periodically as epidemics east of the continental divide in the USA and throughout many countries in the Americas and eastern and southern Africa. In the USA and other parts of the world, rust is particularly damaging to snap beans and to dry bean varieties of certain commercial classes. Rust epidemics can cause yield losses that approach 100% (Lindgren et al., 1995). The seed-borne pathogens BCMV and BCMNV affect seed production in the western USA and other areas of the world, particularly in Africa and Latin America. In these countries having resistance to both viruses is important (Drijfhout and Morales, 2005).

Gene pyramiding for the development of beans with multiple disease resistance genes is the most cost effective strategy for management of the highly variable rust and BCM and BCMN pathogens. These bean germplasm lines are homozygous for four rust and two mosaic resistance genes. BMN-RMR-8, BMN-RMR -9, BMN-RMR-10, BMN-RMR-11, BMN-RMR-12, and BMN-RMR-13 are the first released great northern bean lines to combine the rust resistance genes *Ur-3, Ur-4*, *Ur-6*, and *Ur-11*. The *Ur-3 and Ur-11* rust resistance genes are from small- and medium-seeded beans of the Middle American gene pool, while *Ur-4* and *Ur-6* are from large-seeded beans of the Andean gene pool. These lines also combine the *bc-3* gene that conditions an immune (without any visible symptoms) reaction to all BCMV

M.A. Pastor-Corrales, USDA-ARS, Vegetable Lab., Room 240, Building 010 A, Plant Sciences Institute, Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD 20705-2350; J.D. Kelly, Crop and Soil Sciences Dep., Michigan State Univ., East Lansing, MI; James Steadman, Dep. of Plant Pathology; D.T. Lindgren, Dep. of Agronomy and Horticulture, Univ. of Nebraska, Lincoln, NE; J.R. Stavely, formerly of the Molecular Plant Pathology Lab., and the late Dermot P. Coyne, Dep. of Agronomy and Horticulture, Univ. of Nebraska, Lincoln, NE. A contribution of the Univ. of Nebraska, Agricultural Research Division, Lincoln, NE 68583. Registration by CSSA. Received 30 Dec. 2005. *Corresponding author (talo.pastor-corrales@ba.ars.usda.gov).

Published in the Journal of Plant Registrations 1:77–79 (2007).
doi: 10.3198/jpr2005.12.0517crg

677 S. Segoe Rd., Madison, WI 53711 USA

and BCMNV strains with the hypostatic *I* gene, which conditions resistance to BCMV (Melotto et al., 1996).

The most important rust resistance gene in BMN-RMR-8 through BMN-RMR-13 is *Ur-11*, which is effective against 89 of 90 races of *U. appendiculatus* maintained at Beltsville. The USDA plant introductions PI 181996 and PI 190078 are the sources of *Ur-11*. Both have black seeds and indeterminate growth habit and are photoperiod sensitive, flowering only in short-day conditions. PI 181996 and PI 190078 were introduced from Guatemala in 1949 and 1950, respectively, and their comprehensive rust resistance was identified at Beltsville in the late 1980s (Stavely, 1988). The 108 race of *U. appendiculatus*, for which *Ur-11* is not effective, is controlled by *Ur-3* and *Ur-4*. The *Ur-3* gene is also effective against 44 races maintained at Beltsville and has remained effective against rust in the USA since its introduction some 12 years ago. This gene is also effective in South Africa, where rust is the most devastating disease of dry beans (Liebenberg, 2003). Published research has shown that *Ur-3* is linked to *Ur-11* in repulsion (Stavely, 1998) but the linkage was broken to recombine *Ur-3* with *Ur-11* in previously released pinto (BelDakMi-RMR-14, BelDakMi-RMR-15, BelDakMi-RMR-16, BelDakMi-RMR-17, and BelDakMi-RMR-18) and great northern (BMN-RMR-7) germplasm lines (Pastor-Corrales, 2003). The *Ur-4* gene that also controls race 108 is effective against 29 of the races of *U. appendiculatus* maintained at Beltsville. In addition, all six lines being released contain the *Ur-6* gene that is effective against 22 races. Michigan pinto breeding lines P94207 and P94232 are the sources of the *Ur-3* and *Ur-6* genes and the type II growth habit. Line P94207 released in 1998 as 'Kodiak' has *Ur-3, Ur-6*, *bc-1²*, and *I* (Kelly et al., 1999). The source of *Ur-4* in BMN-RMR-8 through BMN-RMR-13 is the great northern line BMN-RMR-3, into which *Ur-4* had been introgressed from the navy line BelMiDak-RR-2. The original source of *Ur-4* gene, which is present in many snap bean cultivars, is the snap bean 'Early Gallatin'. Pinto line P94232 and great northern line G 94567 are the source of *bc-3*. Several lines and cultivars in the pedigree of BMN-RMR-3 and BDM-RMR-10, BDM-RMR-11, BDM-RMR-12, BDM-RMR-13, and BDM-RMR-14 are the sources of the *I* gene for resistance to BCMV.

BMN-RMR-8, BMN-RMR-9, BMN-RMR-10, BMN-RMR-11, BMN-RMR-12, and BMN-RMR-13 are derived from a series of F_1, F_2, and F_3 crosses, backcrosses, and selections containing desired rust and mosaic resistance genes. These lines were selected from bulked F_5–generation seeds derived from crossing an F_5 pinto plant, like BDM-RMR-14, homozygous for *Ur-3* and *Ur-6* recombined with *Ur-11* genes and for *bc-3* and *I*, with pollen from a selected plant of the great northern germplasm released line BMN-RMR-3 that has *Ur-4*, *Ur-11*, *bc-3*, and *I*. The initial cross was followed by subsequent selections for great northern seed type and desired rust and mosaic disease resistance genes. The pedigree of the F_5 pinto parent used in this cross to produce BMN-RMR-8 through BMN-RMR-13 is Kodiak/9/P94232*2/8/92 BR-3-1084B/7/BR3-1006B/6/88-011-03*2/5/'Aztec'/4/87-039-34*2/3/P0X10//'Fiesta'/PI 190078. The pedigree of BMN-RMR-3, the great northern parent, is G94567/4/G91213*2/3/'Starlight'*2/'Alpine'*3/BMD-RR-2. The pedigree of BMD-RR-2 is 'Mayflower'/4/4-5753/3/Mayflower//NX 040/PI 181996. The pedigree of 4-5753 is C-20*5/Early Gallatin. The rust resistance of progenitor plants of these releases was confirmed by results from inoculations with eight selected races of the bean rust pathogen that produce characteristic reactions in bean plants that have the *Ur-3*, *Ur-4*, *Ur-6*, and *Ur-11* genes. The rust resistance of BMN-RMR-8 through BMN-RMR-13 was also confirmed by inoculation under greenhouse conditions with the same eight selected races of *U. appendiculatus*. Mosaic resistance was confirmed from inoculation with BCMV strains NL4 and/or US 5 and BCMNV strain NL3. Presence of the *I* gene was reconfirmed by using molecular markers tightly linked to the *I* gene (Melotto et al., 1996). The six great northern germplasm lines were selected from 272 rust-resistant great northern lines evaluated in September 2000 at the Saginaw Valley Bean and Sugar Beet Research Farm, Saginaw, MI, for erect plant habit (type II); early maturity, good pod-to-ground clearance; desirable seed size, color, and shape; and high yield. BMN-RMR-8 through BMN-RMR-13 consist of bulked F_6 and F_7 greenhouse seeds from all F_5 plants from the remnant seeds from the same seed lot used for field evaluations.

The resistance of BMN-RMR-8 through BMN-RMR-13 to *U. appendiculatus* is determined by the interaction of their four rust-resistance genes with different races of the rust pathogen and is expressed in a range of resistant reactions that include symptomless to faint chlorotic reaction, chlorotic to well-defined small necrotic reactions, faint chlorotic spots, and tiny uredinia (<0.3 mm in diam.) (Stavely, 1984). The interaction between *Ur-3* and *Ur*-6 genes with the races of *U. appendiculatus* that these genes control results in necrotic spots (HR = hypersensitive reaction). This HR is epistatic to the faint hypersensitive reaction and tiny uredinia (<0.3 mm in diam.) produced by the interaction between the *Ur-11* gene and the races of the rust pathogen that *Ur-11* controls. The interaction between *Ur-4* and the races that this gene controls results in a distinct necrotic reaction (HR) in the absence of other resistance genes. The interaction between the combination of *Ur-4* and *Ur-11* genes with the races that this gene combination controls results in the production of a symptomless to faint chlorotic reaction. Resistance to BCMV and BCMNV is expressed as a symptomless, apparently immune reaction.

Under field conditions all six releases produced erect plants with moderately early maturity, high yield, good pod-to-ground clearance, and large white great northern seeds. BMN-RMR-8 (tested in the field as 5-4051) produced attractive, dull white seeds that averaged 33.9 g 100^{-1} seeds. BMN-RMR-9 (tested in the field as 5-4059) produced white seeds that averaged 34.3 g 100^{-1} seeds. BMN-RMR-10 (tested in the field as 6-1911) produced white seeds that averaged 33.3 g 100^{-1} seeds. BMN-RMR-11 (tested in the field as 6-2267) produced white, rather large seeds that averaged 36.7 g 100^{-1} seeds. BMN-RMR-12 (tested in the field as 6-1772) produced white and large seeds that averaged 35.7 g 100^{-1} seeds. BMN-RMR-13 (tested in the field as 6-2298) produced white, large seeds that averaged 36.3 g 100^{-1} seeds. The seed weight of all six released great northern germplasm lines compared well with the great northern cultivars Alpine (31.2 g 100^{-1} seeds), Weihing (34.5 g 100^{-1} seeds), and Starlight (36.6 g 100^{-1} seeds).

Although BMN-RMR-8 through BMN-RMR-13 are homozygous for the indicated rust and mosaic resistance genes and many other characteristics, they are being released as bulked F_6 and F_7 seeds from numerous F_5 and F_6 plants. Thus, they still have some variability and are likely to be segregating for some characteristics. It is recommended that those who obtain seeds should plant them individually, save the seeds from each plant, and select from the subsequent generations for desired characteristics.

A limited quantity of seed is available from the corresponding author. Seeds of these lines will be deposited in the National Plant Germplasm System to be available for research development of new cultivars or germplasm. When any of these lines contributes to a new cultivar, it is requested that recognition be given to the source.

Acknowledgments

We acknowledge support of the Bean/Cowpea CRSP (USAID Contract No. DAN-1310-G-SS-6008-00).

References

Drijfhout, E., and F.J. Morales. 2005. Bean common mosaic. p. 62–63. *In* H.F. Schwartz, J.R. Steadman, R. Hall, and R.L. Forster (ed.) Compendium of bean diseases. 2nd ed. APS Press, St. Paul, MN.

Kelly, J.D., G.L. Hosfield, G.V. Varner, M.A. Uebersax, and J. Taylor. 1999. Registration of Kodiak pinto bean. Crop Sci. 39:292–293.

Liebenberg, M.M. 2003. Breeding for resistance to rust of dry bean (*Phaseolus vulgaris*) in South Africa. Ph.D. diss. Univ. of the Free State, Bloemfontein, South Africa.

Lindgren, D.T., K.M. Eskridge, J.R. Steadman, and D.M. Schaaf. 1995. A model for dry bean yield loss due to rust. HortTechnology 5:35–37.

Melotto, M., L. Afanador, and J.D. Kelly. 1996. Development of a SCAR marker linked to the *I* gene in common bean. Genome 39:1216–1219.

Pastor-Corrales, M.A. 2003. Sources, genes for resistance, and pedigrees of 52 rust and mosaic resistant dry bean germplasm lines released by the USDA Beltsville bean project in collaboration with the Michigan, Nebraska, and North Dakota Agricultural Experiment Stations. Ann. Rep. Bean Improv. Coop. 46:235–241.

Stavely, J.R. 1984. Genetics of resistance to *Uromyces phaseoli* in a *Phaseolus vulgaris* line resistant to most races of the pathogen. Phytopathology 74:339–344.

Stavely, J.R. 1988. Occurrence of rust resistance in *Phaseolus vulgaris* plant introductions 90758 through 194441. Ann. Rep. Bean Improv. Coop. 31:128–129.

Stavely, J.R. 1998. Recombination of two major dominant rust resistance genes that are tightly linked in repulsion. Ann. Rep. Bean Improv. Coop. 41:17–18.